River Flow

River flow or discharge is an important factor that influences water quality in riverine systems. Periods of high flow reflect times of increased precipitation and runoff from the basin's tributary streams that may account for substantial nonpoint source pollutant inputs, especially from watersheds where agricultural land use is prevalent. Conversely, periods of low flow in times of drought may amplify the impacts of point source discharges, since there is less river water available for dilution of wastewater inputs. River flow also has a significant influence on the hydraulic residence time (i.e. flushing) of Lake Pepin and the UMR navigational pools. Hydraulic residence time influences mixing, sedimentation, nutrient cycling, phytoplankton production, and other physical, chemical and biological processes in Lake Pepin and the UMR pools. As a result of these factors, most water quality parameters are correlated with river flow, which needs to be considered when interpreting water quality data collected from riverine systems.

The flow data submitted by the contributing agencies are compiled in the “Mainstem Data Universe” and the “Summer Data 1980-1999" data files on the CD which accompanies this report. River flow is not commonly measured or reported by the agencies providing water quality data for the UMR, and the resulting body of flow information is inconsistent. The boxplot diagrams of the submitted flow data over four time periods are depicted in Figure 8. Although the lack of consistent flow data does not seriously impact the general river-wide water quality assessments presented in this report, additional flow data would be required to conduct a more thorough evaluation of flow-related impacts and constituent loading estimates.

Main channel flow data are available from several USGS gaging stations and the navigational lock and dams operated by the US Army Corps of Engineers. Flow data from three selected USGS gaging stations, Winona, MN (RM725.7), Grafton, IL (RM 218), and Thebes, IL (RM 43.7) were analyzed. Average summer (June-August) river flows at the three USGS gaging stations were plotted to illustrate year-to-year flow differences at the different stations of the river (Figure 7). In general, the overall temporal (year-to-year) pattern was very similar at the three gaging sites. Average summer river flows were substantially below normal during the 1987 to 1989 period, and extremely high flows occurred during the flood of 1993. Average summer flows during the remainder of the 1980 to 1999 period were near or above the long-term average (approximately 1930 To 1999) for that gaging station. The average summer flow increases substantially from about 30,000 cfs at Winona, MN to over 200,000 cfs at Thebes, IL reflecting the large increase in basin drainage area over this river reach.

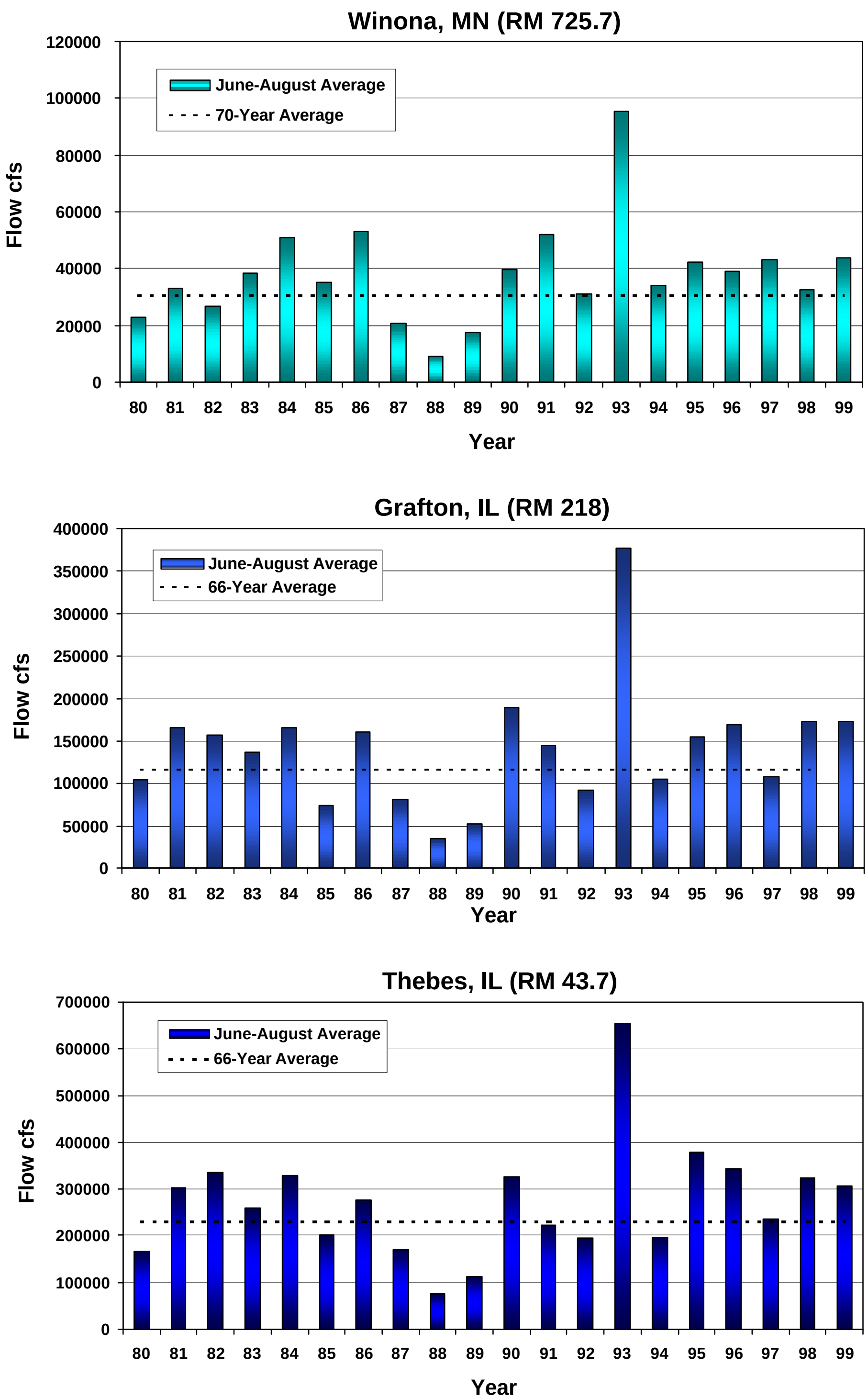
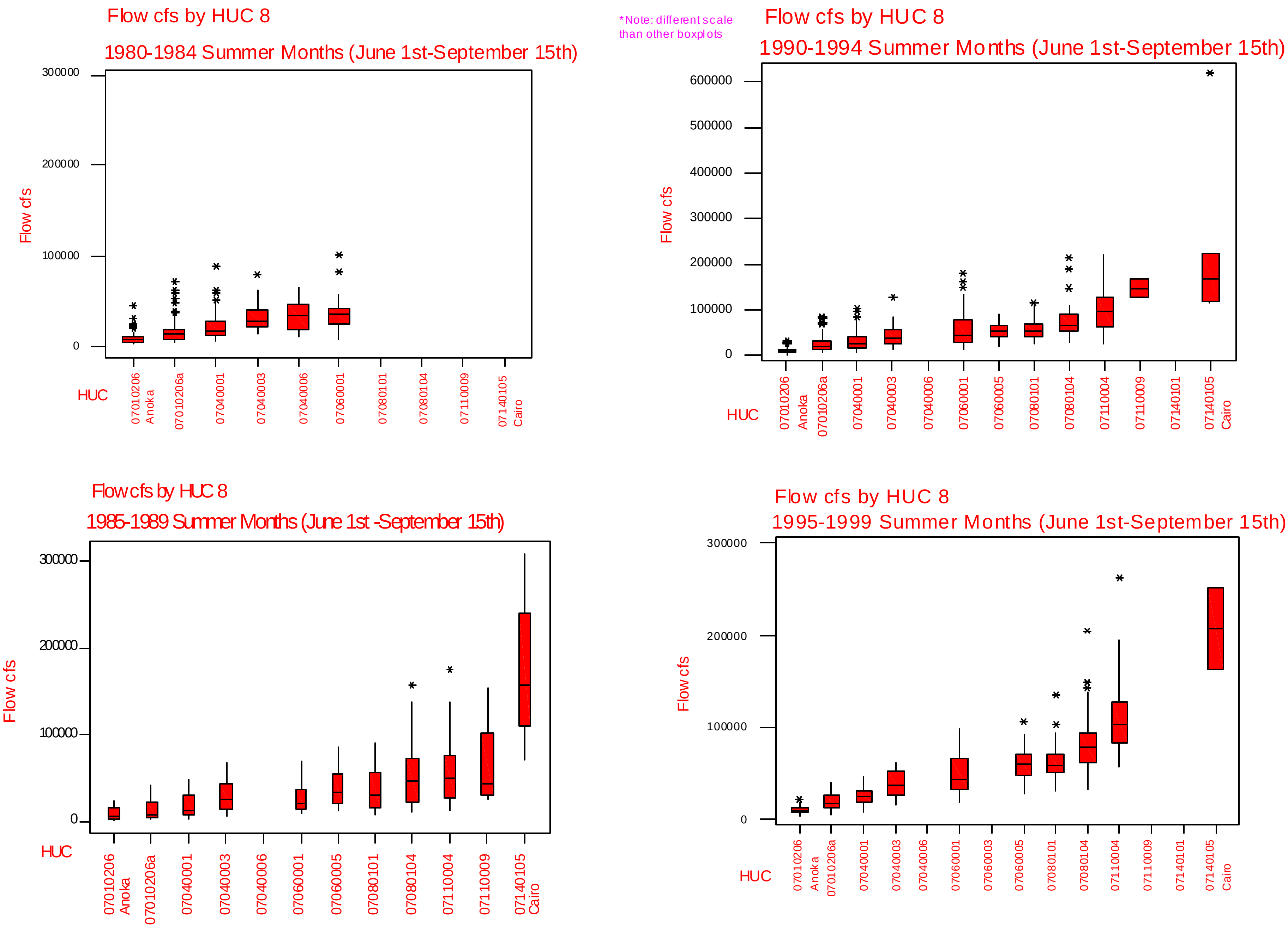


Figure 7. Average summer (June-August) river flow at three USGS gaging stations in the Upper Mississippi River.

Figure 8: Boxplots of Flow Data by HUC over four time periods



Water Temperature

Water temperature is an important physical parameter that influences aquatic plant and animal communities, especially as it relates to limnological, chemical, and biological processes. Water temperatures typically ranged from about 15 to 30 degrees Centigrade (°C) in the study area during the summer season (Figure 9). Temperatures increase about 5 °C from the upper to the lower reaches of the UMR, consistent with climatic differences along this longitudinal gradient. A comparison of temperature ranges between the four summer time periods (Figures 9 and 10) does not reveal any notable differences for those sites where monitoring data have been consistently collected. The boxplot diagrams (Figures 10 and 11) show a slight increase in the median river temperature, proceeding from north to south.

Dissolved Oxygen

Dissolved oxygen (DO) is a critical water quality parameter, and its presence or absence has a dramatic impact on the distribution and abundance of fish and aquatic life in the UMR. All of the states bordering the Upper Mississippi River have established a water quality criterion of 5 mg/L to protect and support aquatic life use, including fisheries. This criterion provides a useful reference for spatial and temporal comparisons.

Summer DO concentrations during four time periods generally ranged from about 5 to 12 mg/L in the Upper Mississippi River (Figure 12). DO levels below 5 mg/L have been reported and were most apparent below the Twin Cities Metropolitan Area in the 1980s. In the 1990s, DO concentrations in this reach improved noticeably, primarily as a result of advanced wastewater treatment technology (Johnson and Aasen, 1989; USEPA, 2000). During the 1995 to1999 period, DO levels below 5 mg/L were observed in a 150-mile segment of the river extending from Pool 9 to Pool 14 (RM 648 to RM 500). It is suspected that the marked growth and expansion of zebra mussel populations in this reach in 1997 may have contributed to low DO levels, due to zebra mussel respiratory demands and excretory products (Sullivan and Endris, 1998). Additional factors contributing to reduced DO levels in this reach during the 1995 to 1999 period could include increased biochemical oxygen demand and reduced algal and aquatic plant photosynthesis caused by polluted runoff and turbid inflows following major rainfall events.

DO concentrations exceeding 15 mg/L were apparent in Pool 8 during the 1990 to1994 period and likely reflect periods of high photosynthetic activity. DO concentrations in the open river reach were generally lower and less variable. This may indicate higher water temperatures (lower DO saturation), increased biochemical oxygen demand and decreased photosynthetic activity. The DO boxplot diagrams (Figures 13 and 14) show a very slight decrease in the median DO concentration, proceeding from north to south.

Figure 9 - Water Temperature in the Upper Mississippi River

Summer Data Collected over Four Time Periods

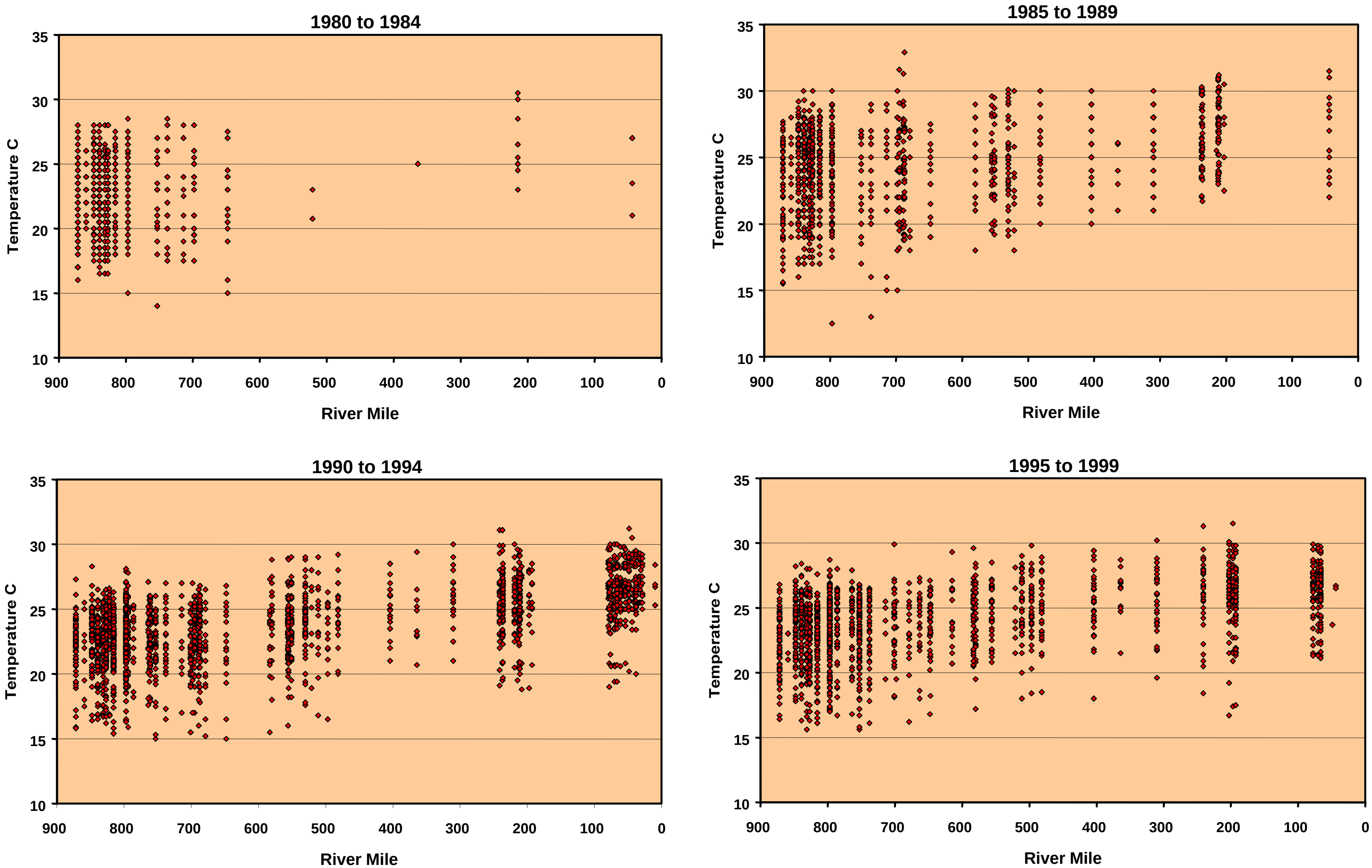


Figure10: Boxplots of Temperature Data by HUC over four time periods

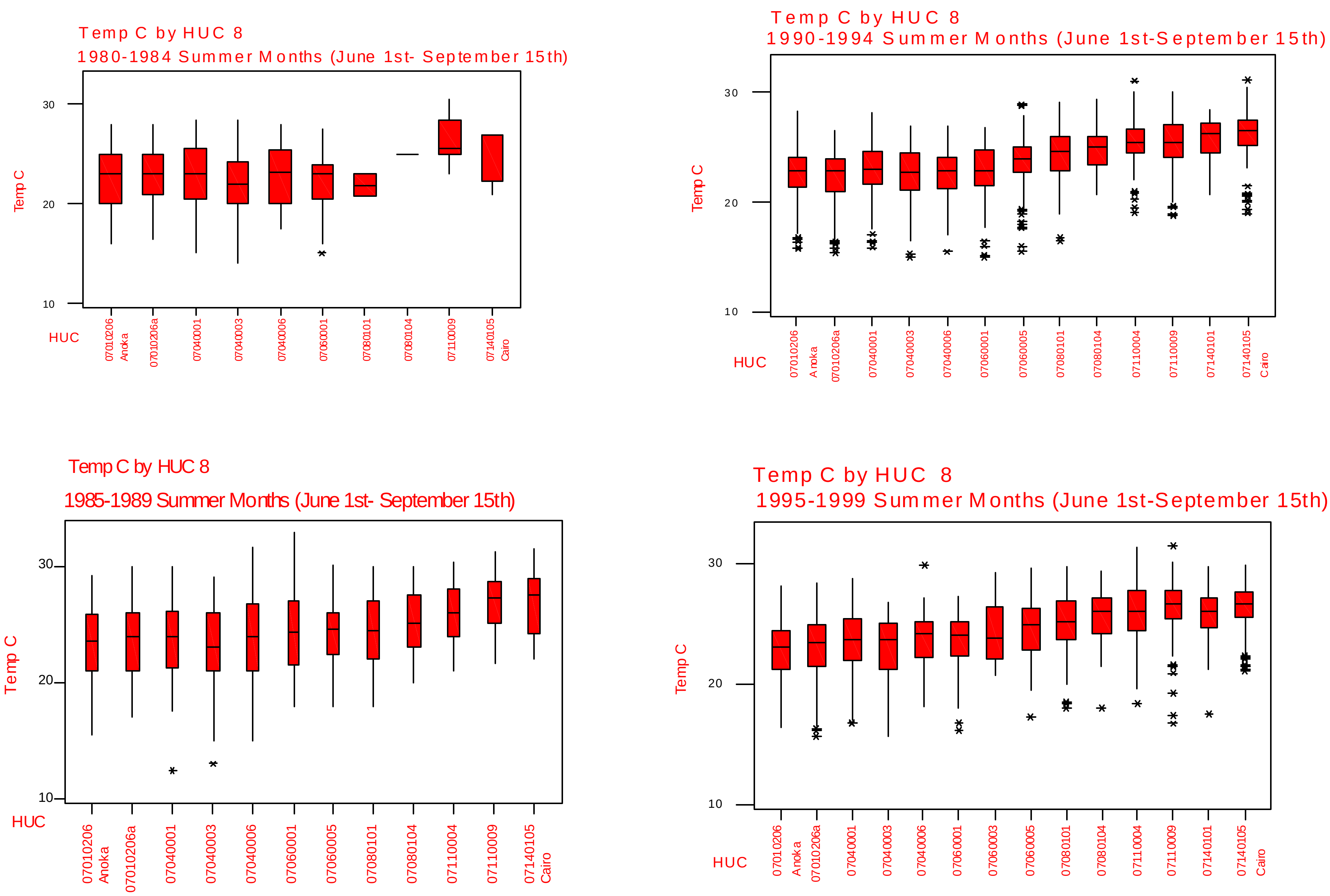


Figure 11: Boxplot of Water Temperature Data by HUC over 20 years

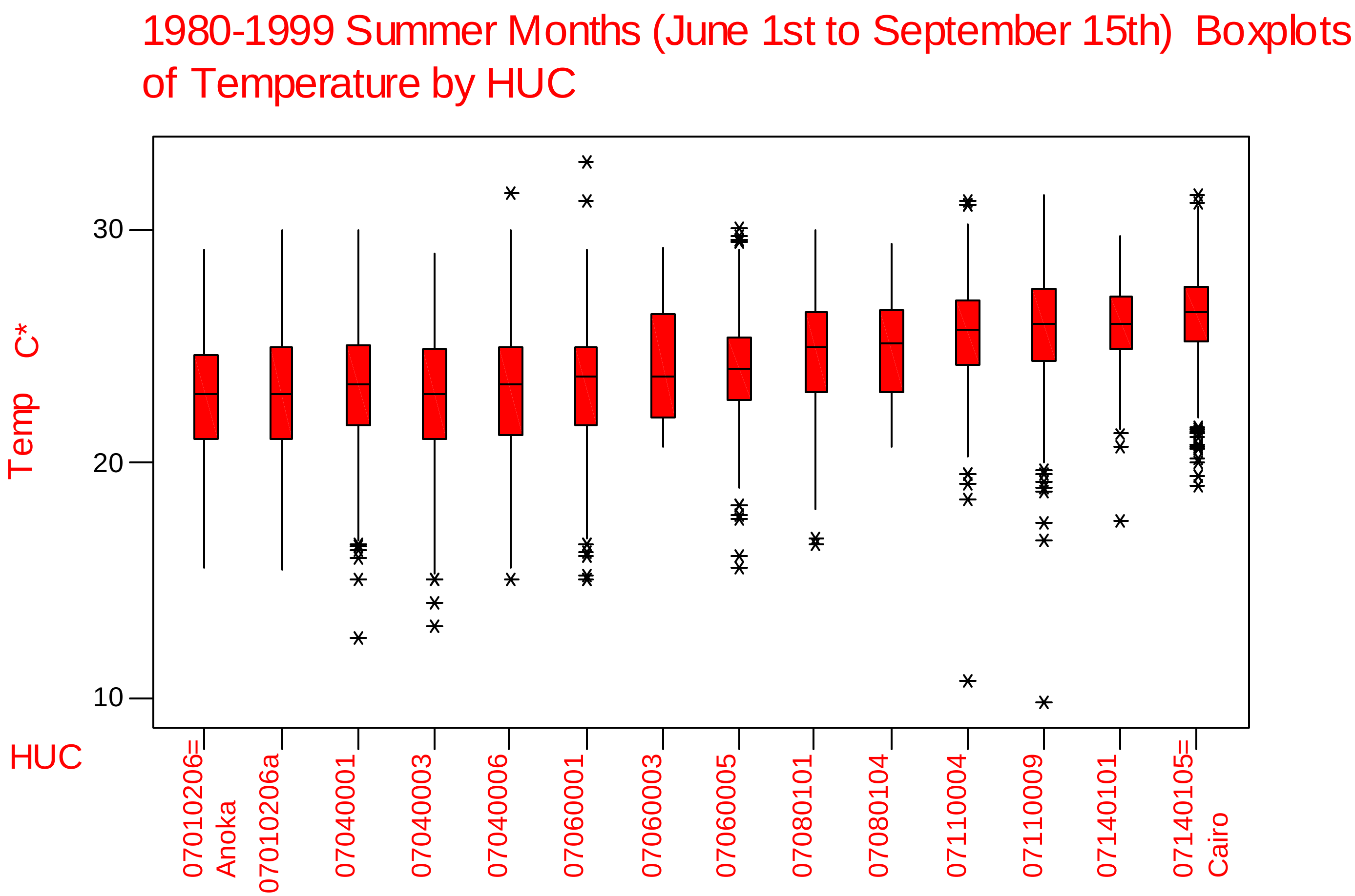


FIGURE 12

Dissolved Oxygen Concentrations in the Upper Mississippi River

Summer Data Collected over Four Time Periods.

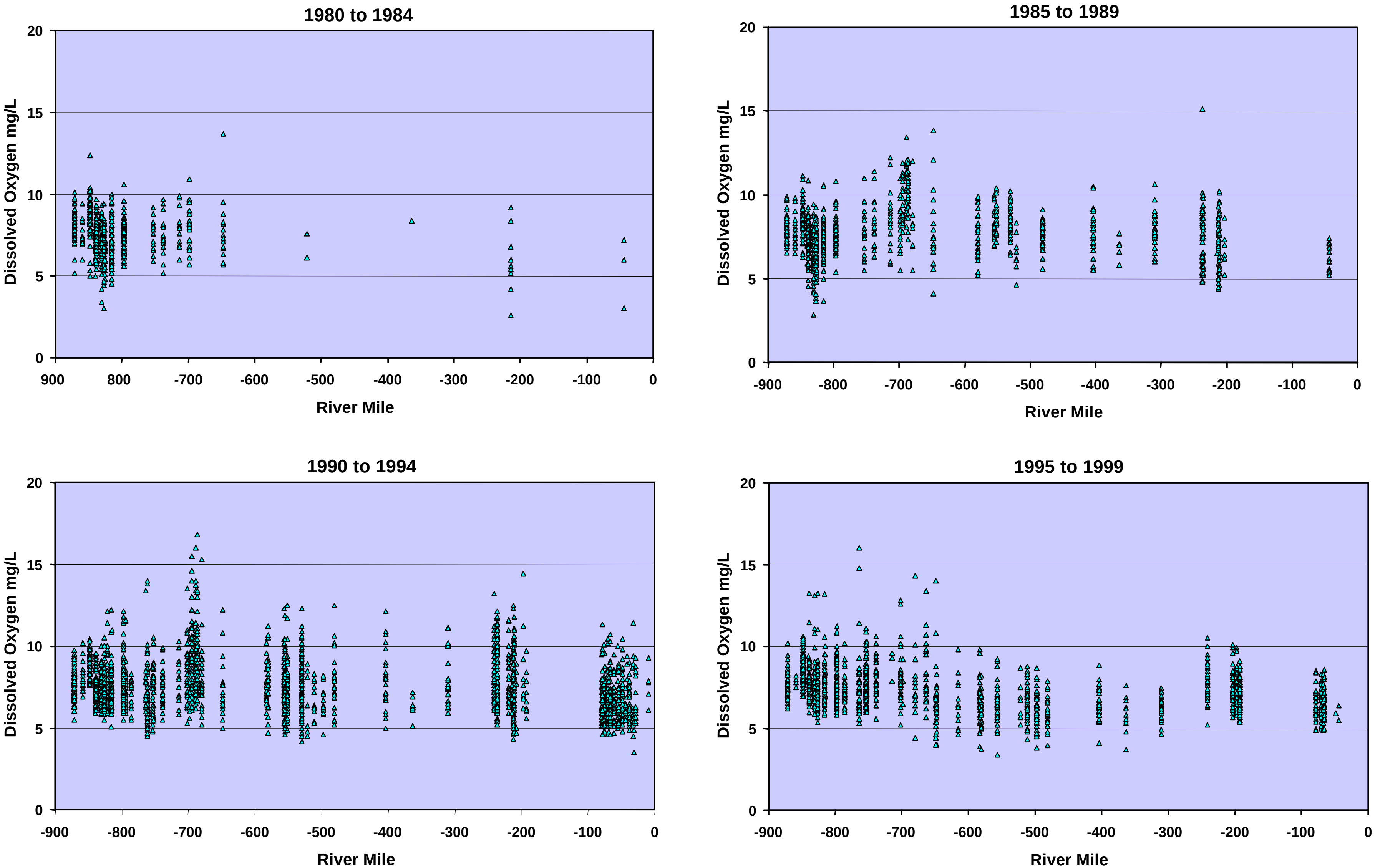


Figure13: Boxplots of DO Data by HUC over four time periods

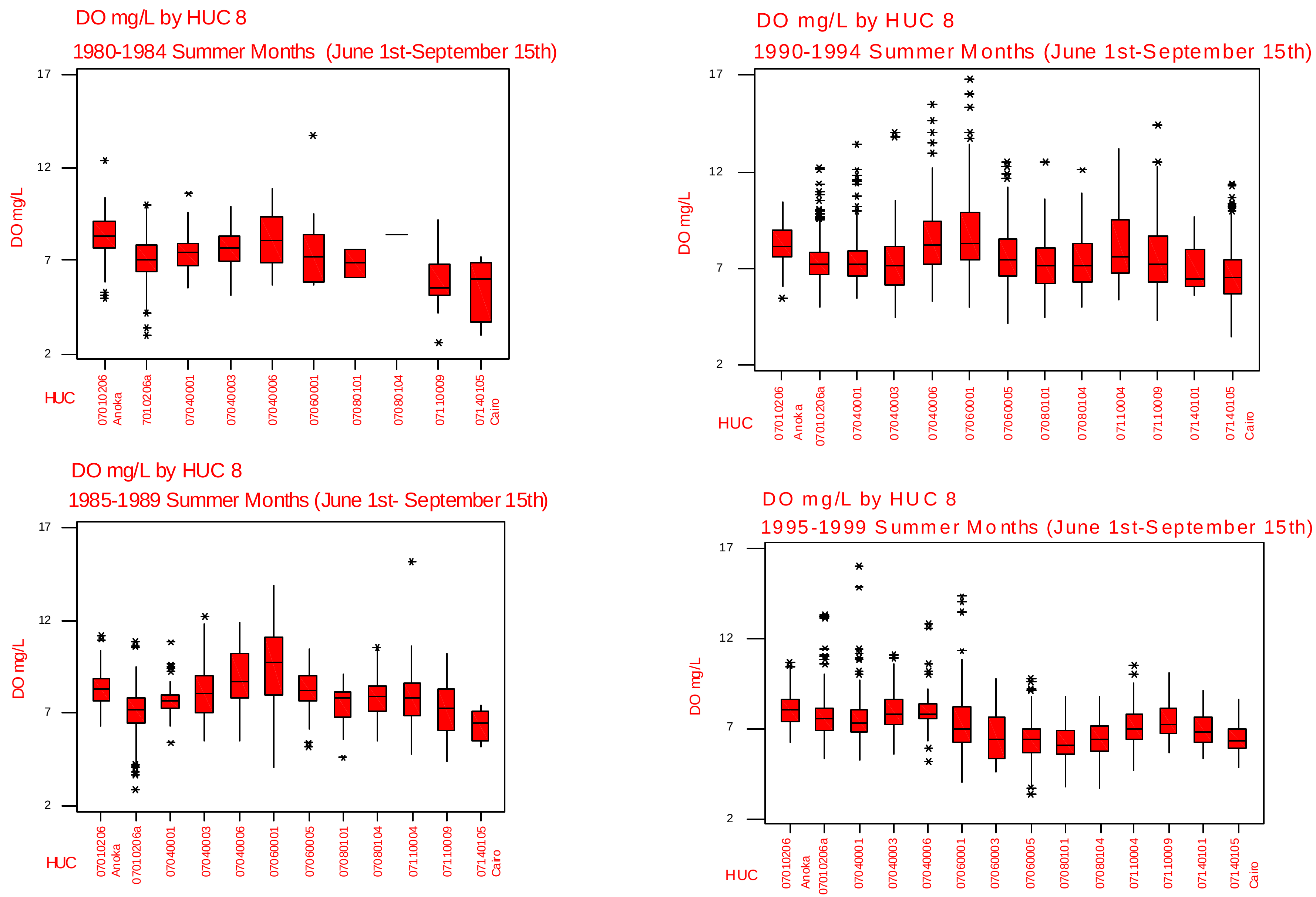
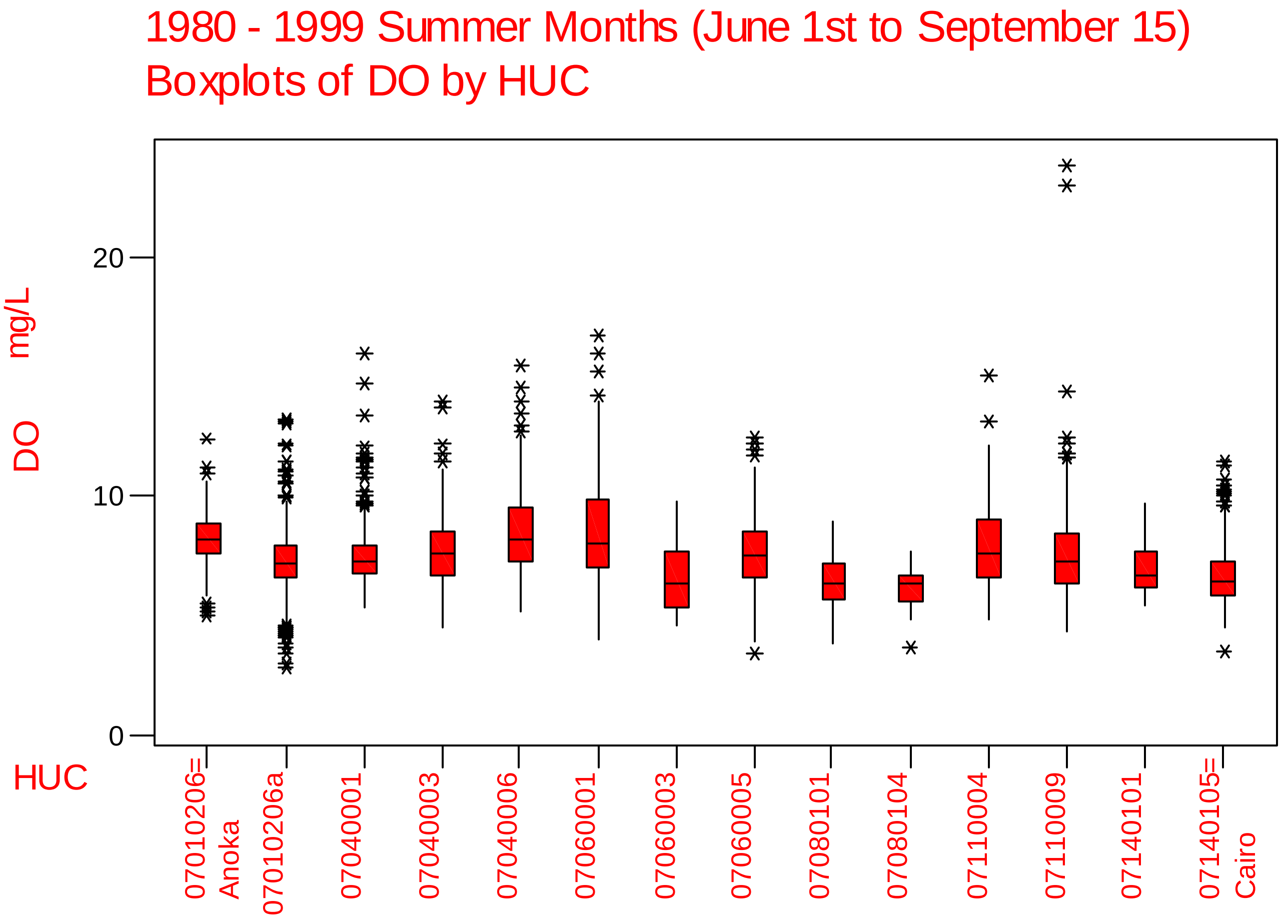


Figure 14: Boxplot of DO Data by HUC over 20 years



Specific Conductivity

Specific conductivity is a measure of water's capacity to conduct an electrical current. Conductivity increases with increasing temperature and dissolved solids concentration. Since specific conductivity measurements are temperature-adjusted to 25 °C to discount the influence of water temperature, specific conductivity provides an approximate indication of the dissolved solids content of water.

The longitudinal profile of specific conductivity in the UMR provides a unique pattern that is primarily influenced by tributary inflows (Figure 15). A marked increase in specific conductivity occurs below the Minnesota River (RM 844), a tributary with high concentrations of dissolved solids. Downstream from the Minnesota River confluence, conductivity levels decreased markedly as large tributary inflows (St. Croix, Chippewa, and Black Rivers) with lower dissolved solids concentrations act to dilute the Mississippi River. The conductivity profile then flattens until the Illinois and Missouri Rivers enter the Mississippi at RM 218 and RM 195, respectively. These two rivers add substantial loads of dissolved solids to the Mississippi, thereby increasing conductivity levels. No clear temporal pattern is evident when summer data for specific river segments are compared over the four time periods. The boxplot diagrams (Figures 16 and 17) show an increase in conductivity below the Minnesota River confluence, followed by a marked decline. Another increase is apparent below the confluence with the Missouri River.

Field and Laboratory pH

Measurements of pH provide an index of the acidity or alkalinity of water. Most UMR states have adopted a standard that incorporates a pH range from 6 to 9 units to protect and support aquatic life use, including fisheries. Monitoring agencies have typically used different methods to measure pH, including field and/or laboratory determinations. To illustrate the entire data set, both field and laboratory pH measurements were plotted on the same graph, noting that laboratory measurements were particularly important to get good coverage of sites during the 1980-1984 and 1985-1989 time periods (Figure 18). No attempt has been made to assess the potential bias that may be inherent in these different methods for measuring pH.

Most summer pH values in the UMR ranged from 7 to 9 units, thus normally supporting full fish and aquatic life standards (Figure 18). At a number of locations during several time periods, summer pH values exceeded 9. These elevated pH values were likely the result of high levels of photosynthetic activity. Field pH values were used to construct the boxplots in Figures 19 and 20. No clear temporal trend was obvious in these figures. Consistent longitudinal patterns were also not apparent.

FIGURE 15 Conductivity in the Upper Mississippi River

Summer Data Collected over Four Time Periods

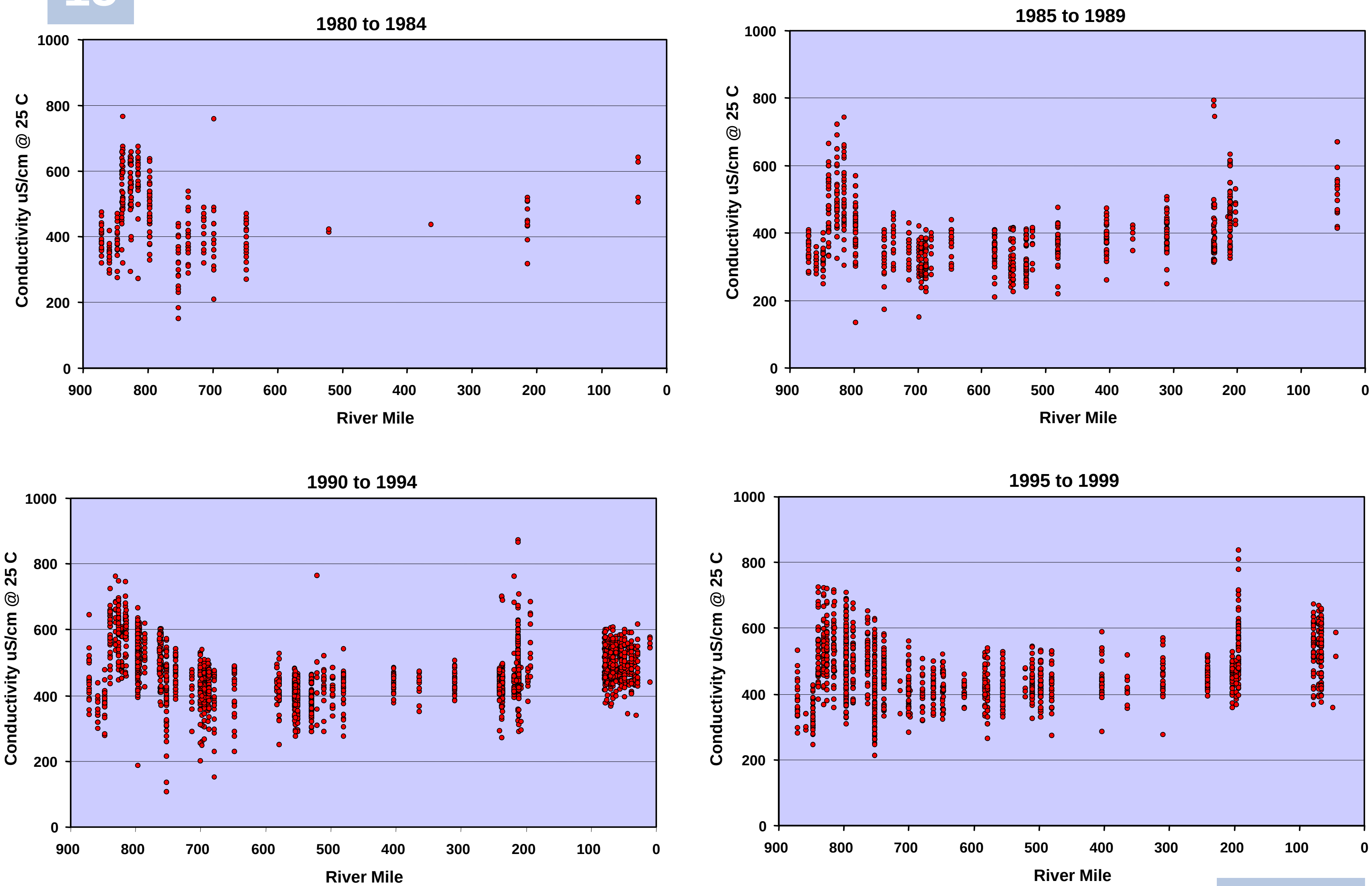


Figure 16: Boxplots of Conductivity Data by HUC over four time periods

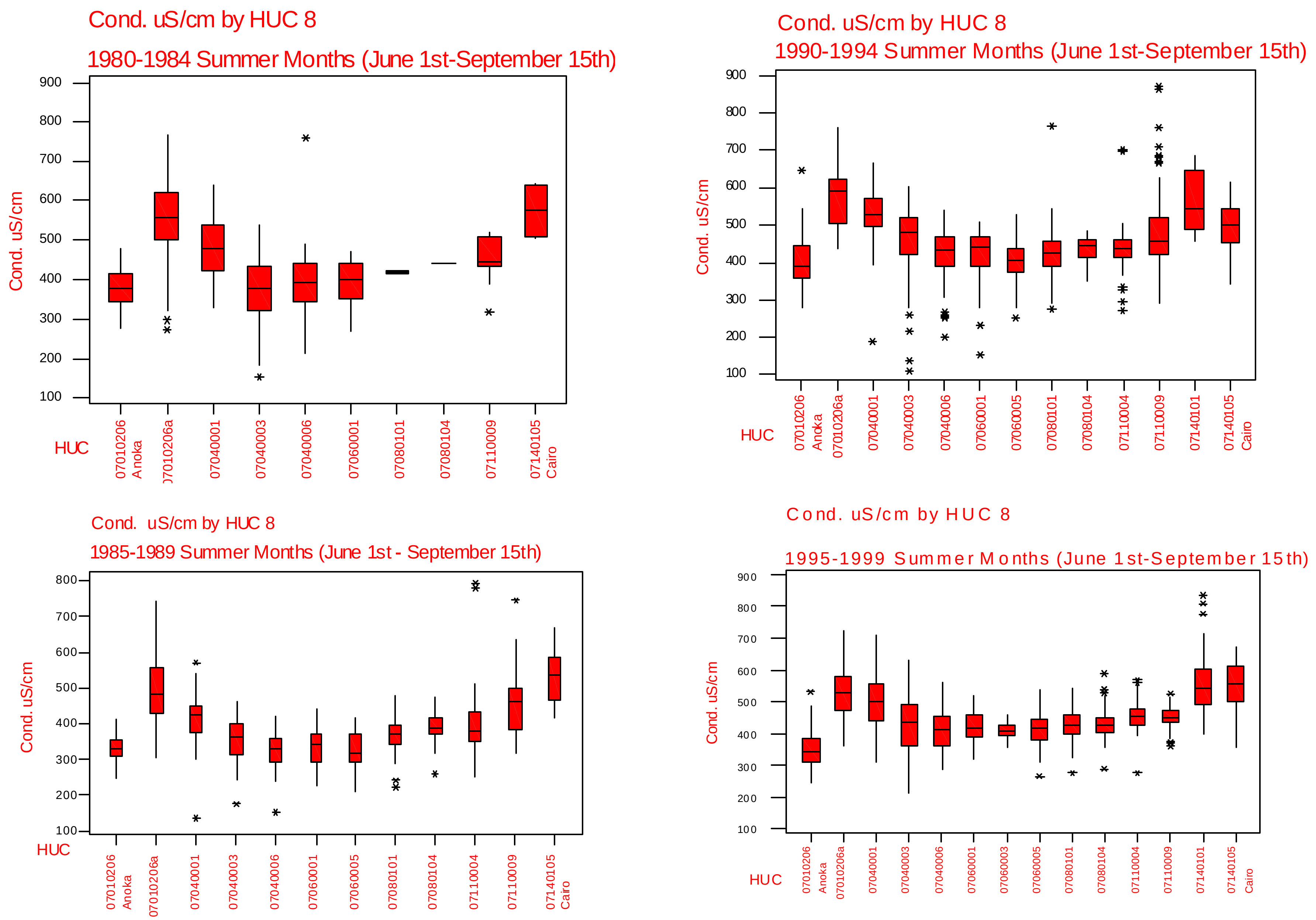


Figure 17: Boxplot of Conductance Data by HUC over 20 years

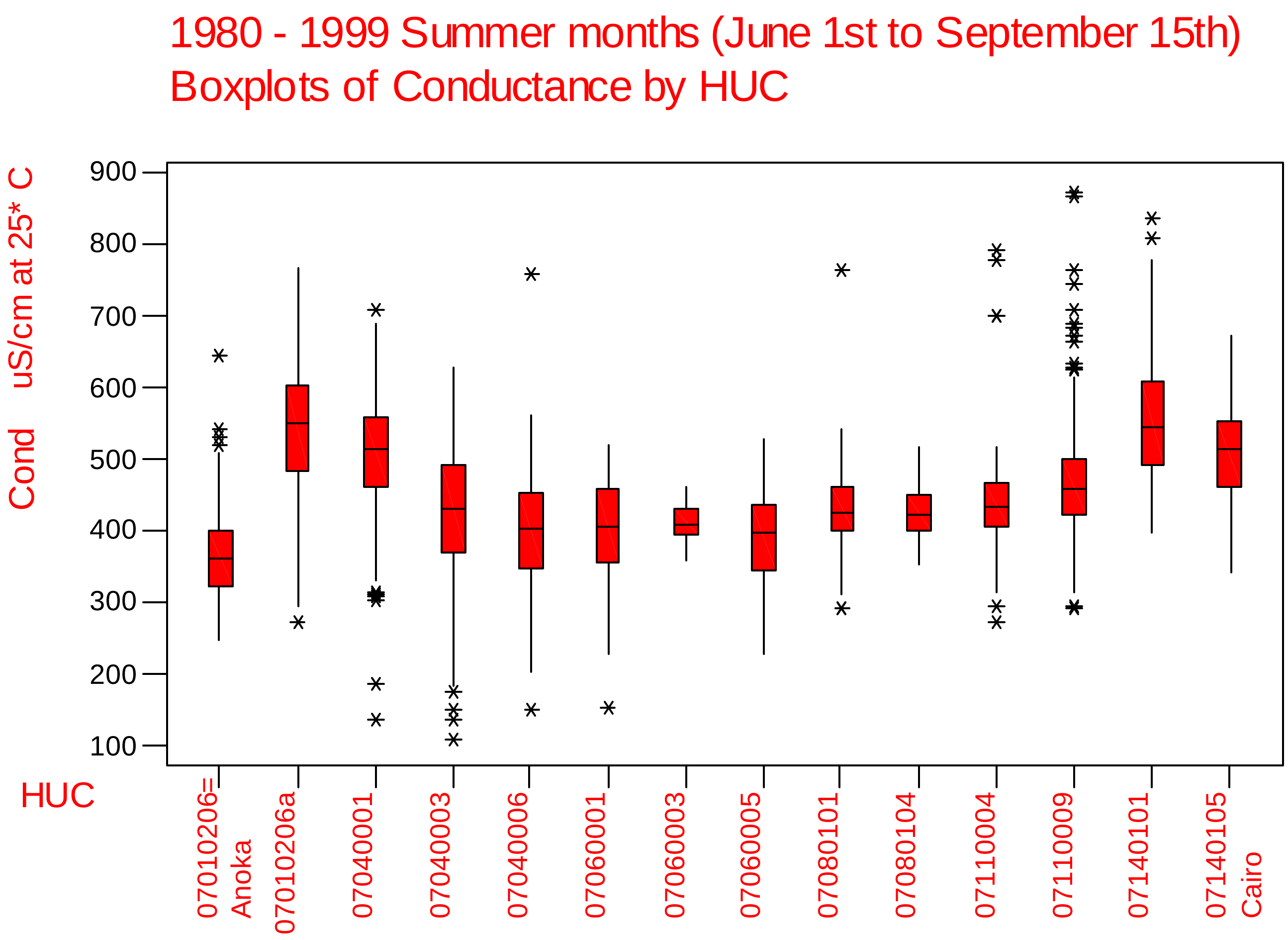


Figure 18 - Field and Lab pH in the Upper Mississippi River

Summary Data Collected over Four Time Periods

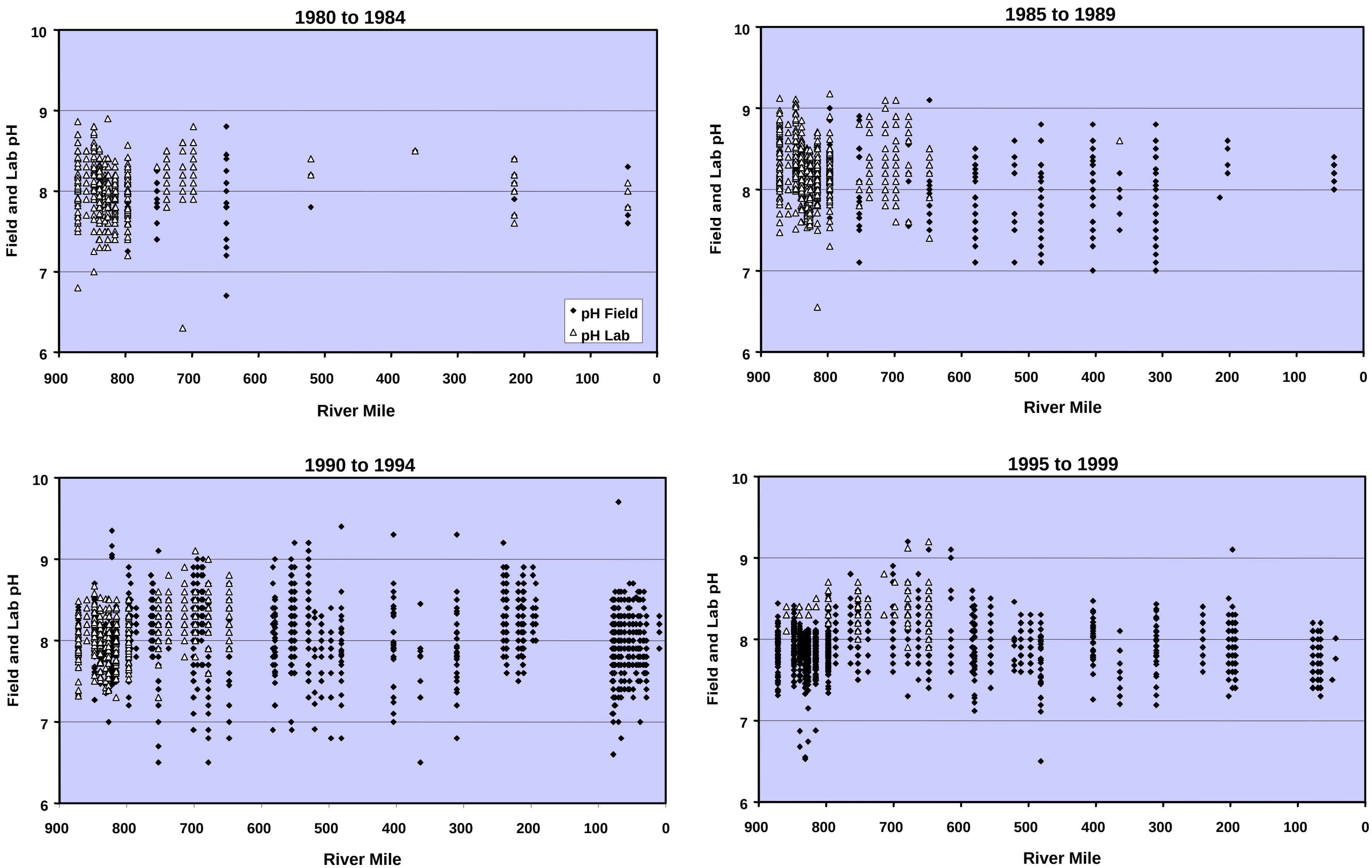


Figure 19: Boxplots of Field pH Data by HUC over four time periods

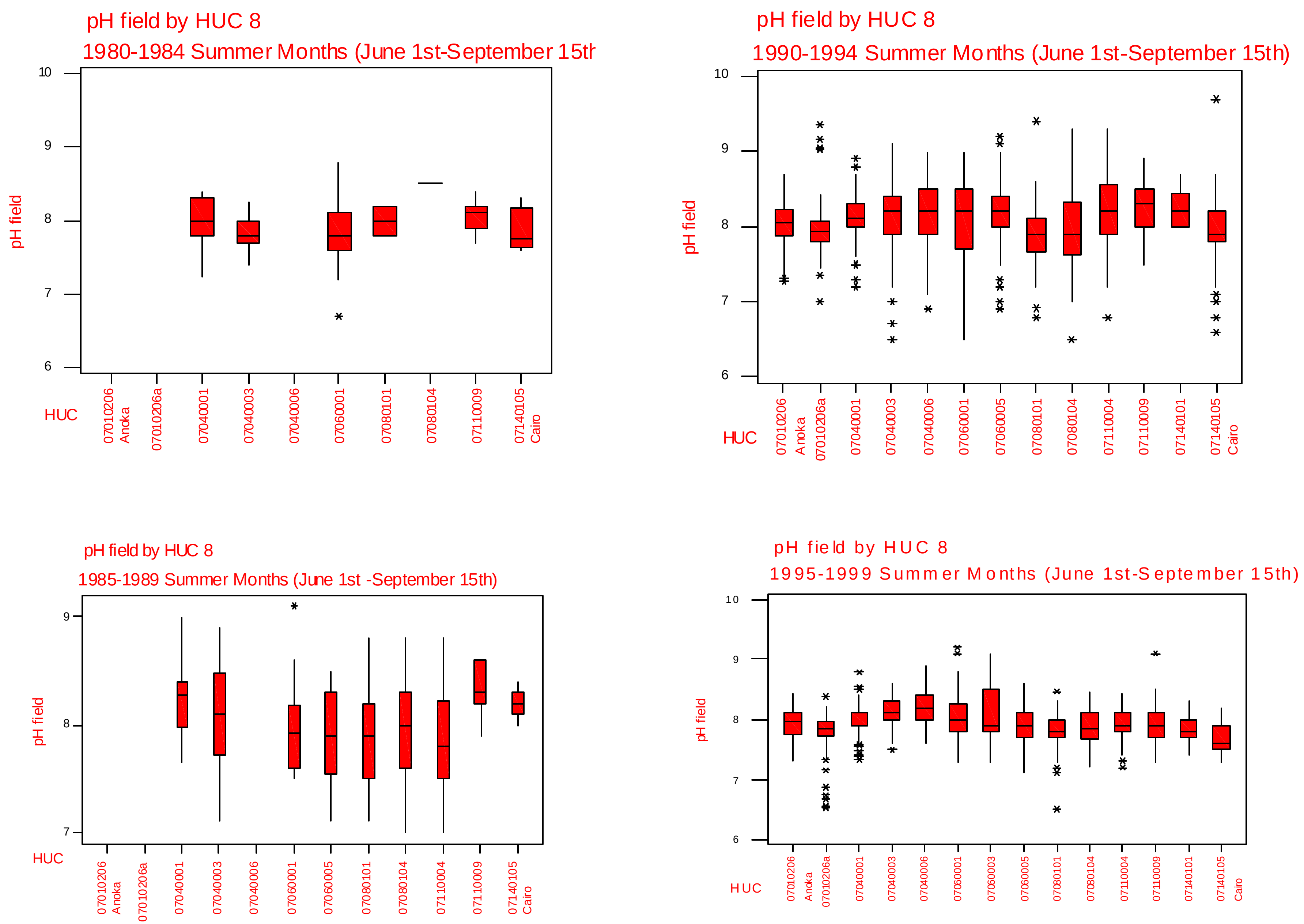
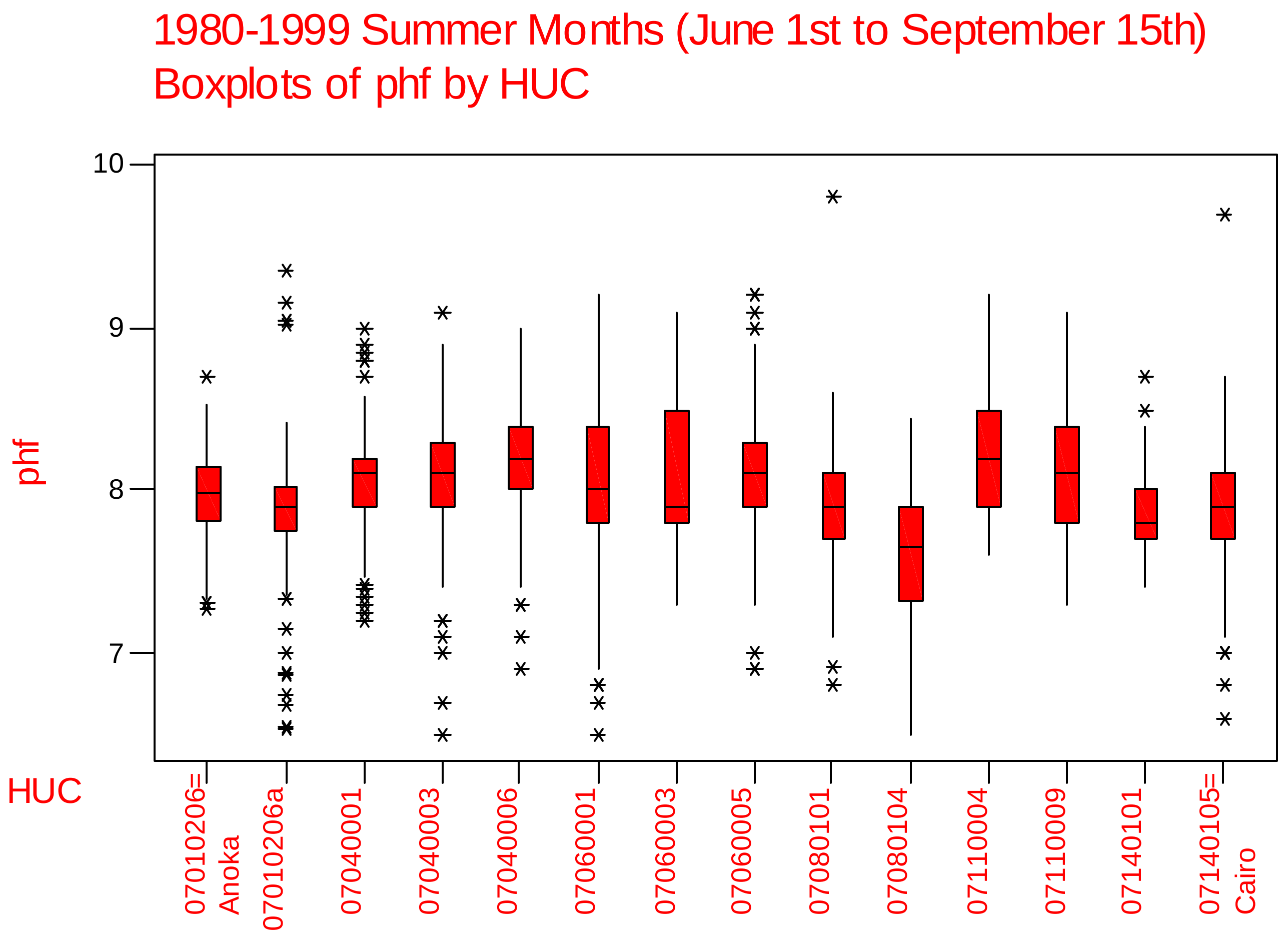


Figure 20: Boxplot of Field pH Data by HUC over 20 years



Total Nitrogen

Nitrogen in surface water may be present in various organic and inorganic forms. As a result, the estimation of total nitrogen content may be based on direct analytical determination, or the combined sum of individual forms such as organic nitrogen, ammonia, nitrite, and nitrate. Nitrogen is an important plant nutrient and has been used in agricultural fertilizers to stimulate the production of agricultural crops, especially corn. Runoff from areas with intensive cultivation or large livestock densities is an important sources of nitrogen. In addition, certain industrial discharges and municipal wastewater effluents may contain high concentrations of inorganic nitrogen, especially ammonia or nitrate nitrogen. In oxygenated surface waters, including the Mississippi River, the dominant form of nitrogen is normally nitrate. As a result, total nitrogen concentrations closely follow the patterns and trends exhibited by nitrate nitrogen. On a national scale, excessive nitrogen input from the Mississippi River to the Gulf of Mexico has been implicated in nutrient enrichment and hypoxic conditions in the Gulf (CENR, 2000).

Total nitrogen concentrations in the Upper Mississippi River increase markedly in Pool 2 (RM 847.5 to RM 815) is a result of agricultural inputs from the Minnesota River Basin and point source contributions from the Twin Cities Metropolitan Area (Figure 21). Concentrations decrease downstream due to dilution from tributaries with lower nitrogen levels, nutrient assimilation by aquatic plants, denitrification, and sedimentation of particulate organic nitrogen. Nitrogen concentrations increase again below Le Claire, IA (RM 497), likely due to increased nitrogen loading from Iowa and Illinois tributaries. Based on Pool 2 data collected over the 20-year period, total nitrogen levels were higher in the 1990s than in the 1980s (Figures 21 and 22). A similar temporal comparison for the lower reach of the UMR was not possible due to the unavailability of data for the early time periods (Figures 22 and 23).

Total Nitrite + Nitrate Nitrogen

Nitrite is a reduced form of inorganic nitrogen that is normally found in low concentrations in surface waters. Many laboratories, including those providing data for this report, use analytical methods that yield a combined concentration of nitrite + nitrate nitrogen, since analysis of the individual ions requires separate analytical techniques. Most states recognize a nitrate drinking-water standard of 10 mg/L for those reaches where surface water serves as a potable water supply.

Total nitrite+nitrate nitrogen (NOx) concentrations, ranged from about 1 to almost 10 mg/L in the UMR (Figures 24, 25, and 26). As expected, NOx concentrations follow a similar longitudinal profile to that described for total nitrogen, since inorganic nitrogen (NOx) comprises a considerable proportion of total nitrogen. Municipal point source inputs and nonpoint source contributions from agricultural areas are important sources of

Figure 21 - Total Nitrogen Concentrations in the Upper Mississippi River

Summer Data Collected over Four Time Periods

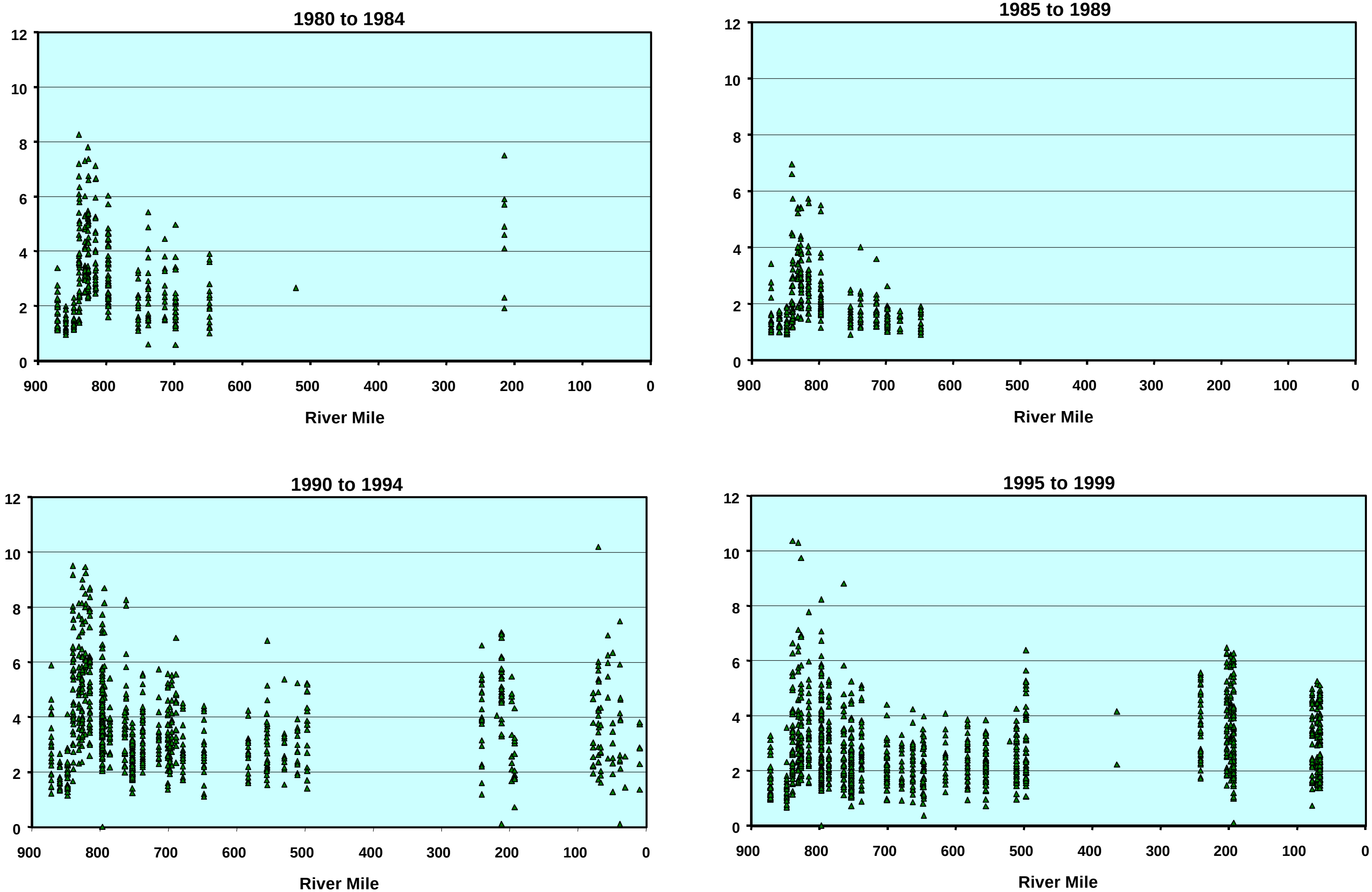


Figure 22: Boxplots of Total Nitrogen Data by HUC over four time periods

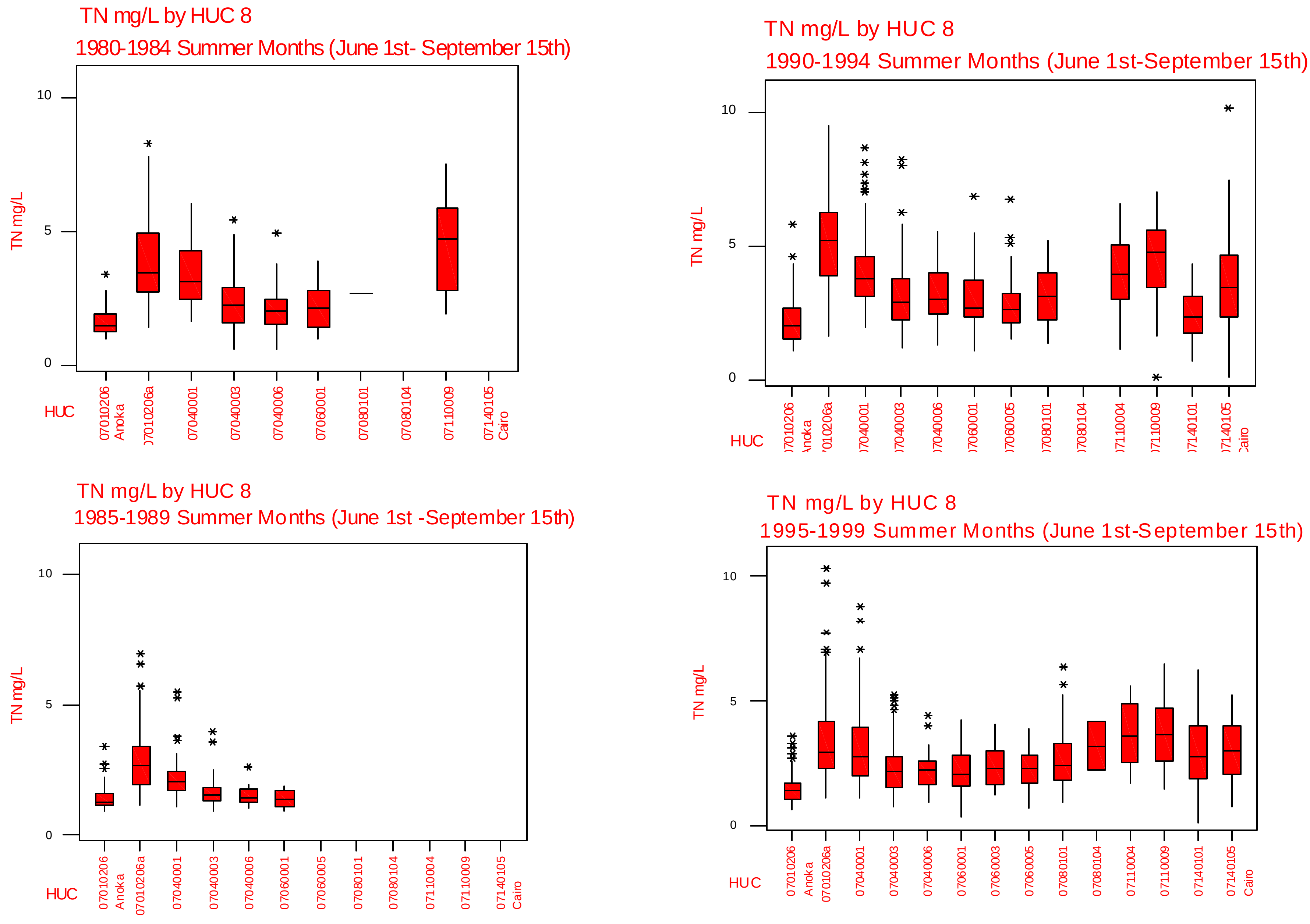


Figure 23: Boxplot of Total Nitrogen Data by HUC over 20 years

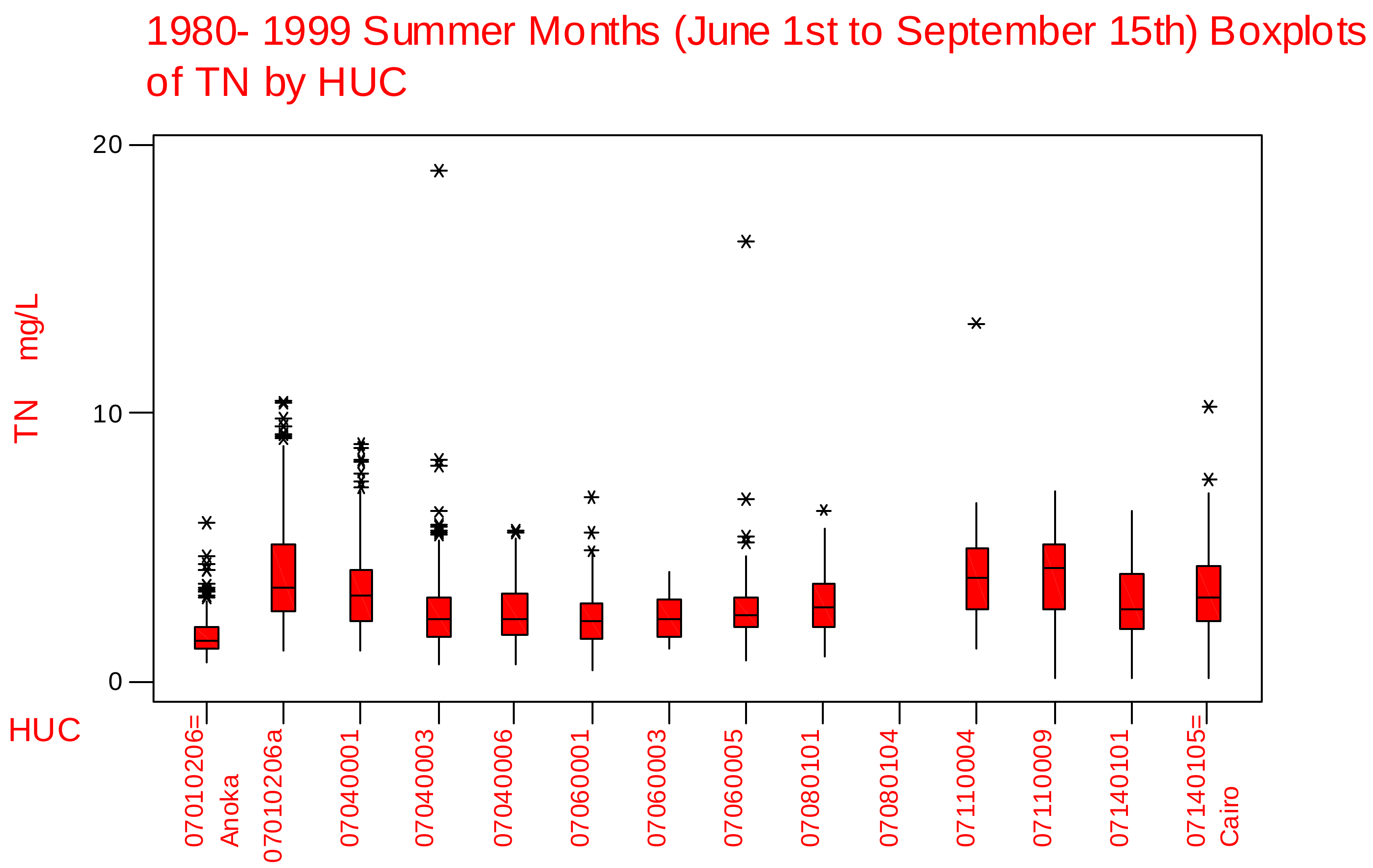


Figure 24 - Total Nitrite+Nitrate Nitrogen Concentrations in the Upper Mississippi River

Summer Data Collected over Four Time Periods

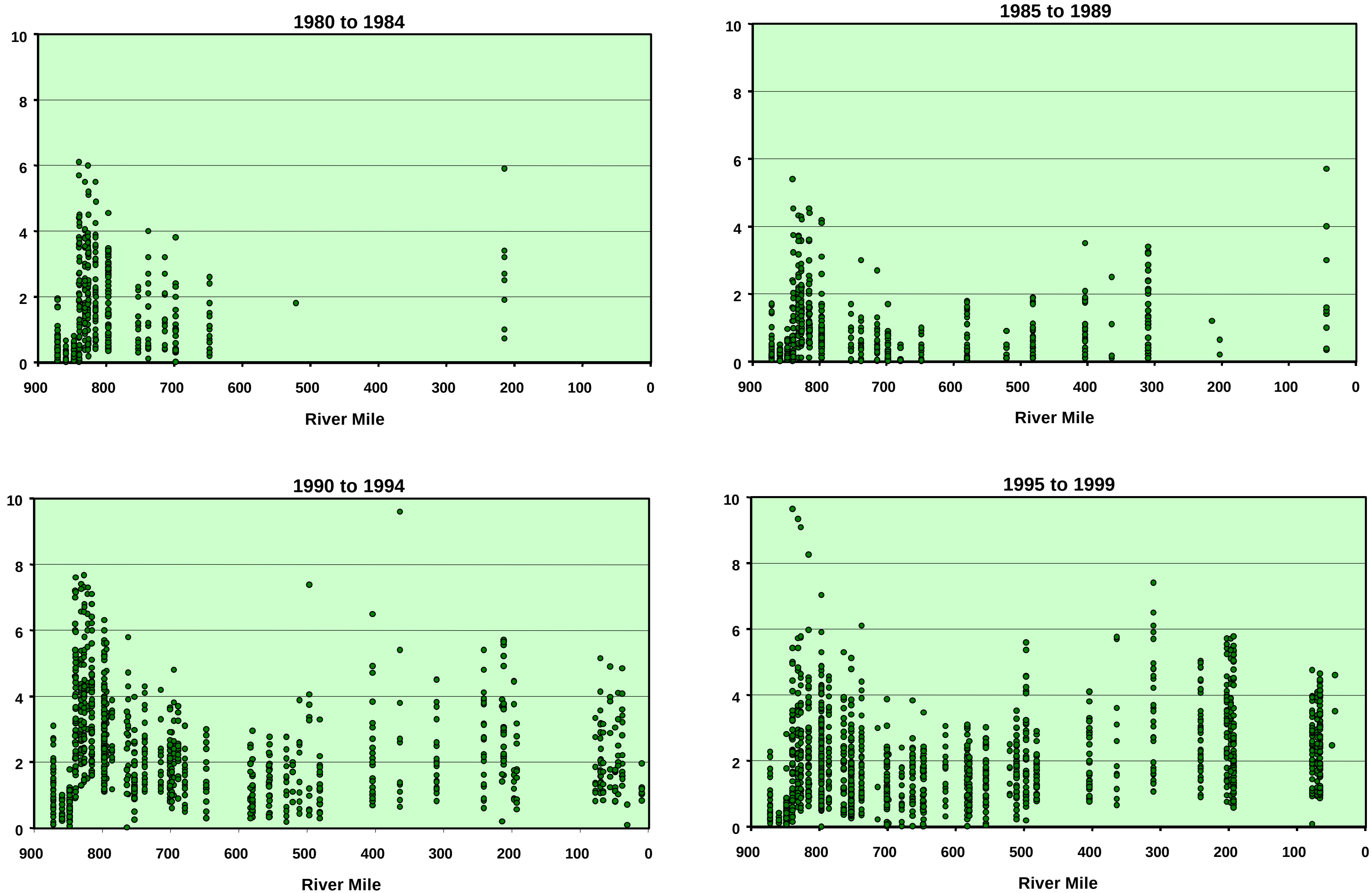


Figure 25: Boxplots of NOx Data by HUC over four time periods

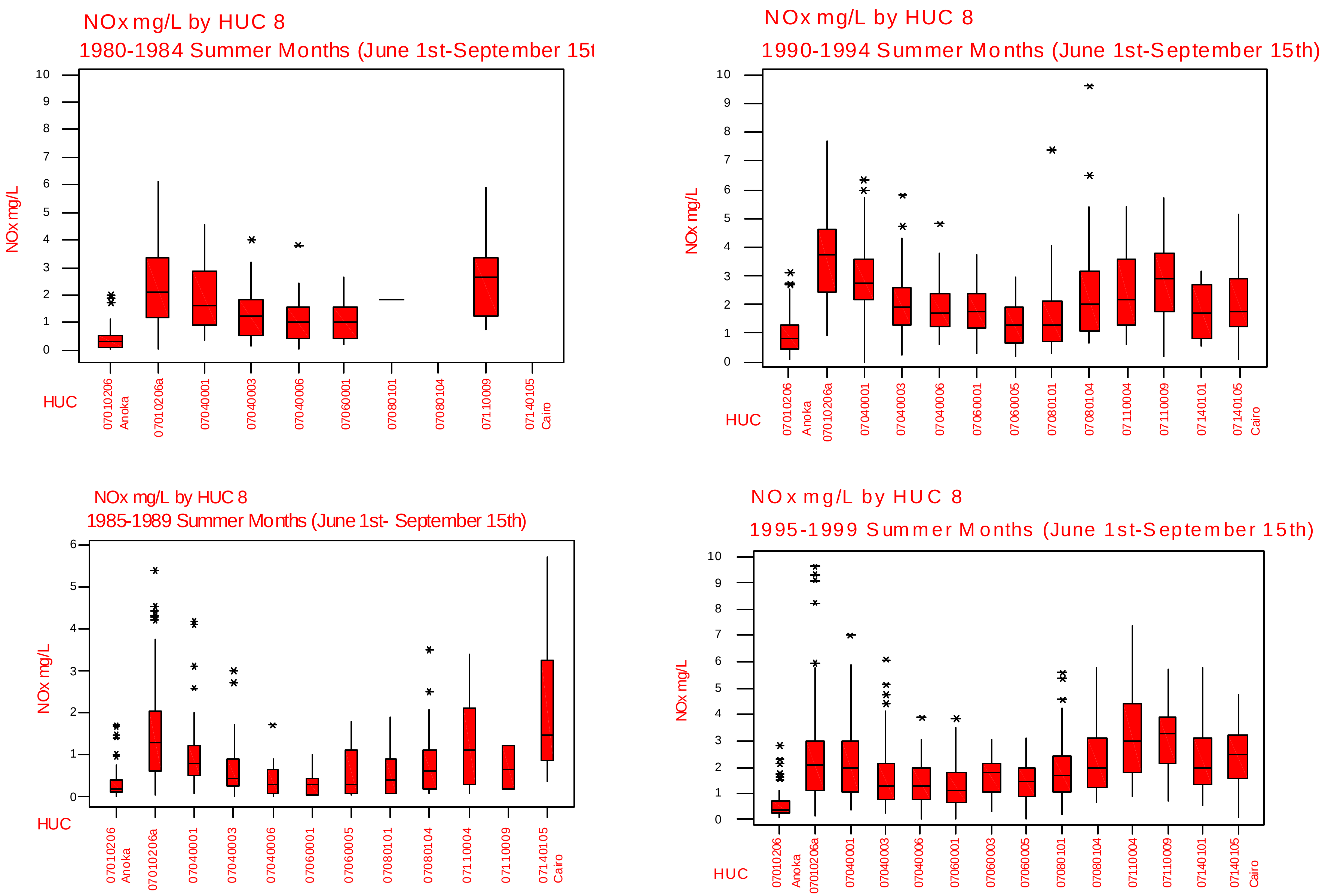


Figure 26: Boxplot of NOx Data By HUC over 20 years